Simulation Tasks

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Solvers and stiff systems

- Average time: 6.8 hours (std = 1.8 h)
- Time range: 5 to 9 hours
- Deadline was fairly well respected
- Only a short introduction to a vast field
- Results depend partly on computer, OS, 32 or 64 bit OS/Matlab and also Matlab version
- Conclusion: selection of solver and way to set up the problem is important

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Multivariate monitoring

- Average time: 6 hours (std = 1.4 h)
- Time range: 5 to 8 hours
- Deadline was very well respected
- Only a short introduction to a huge field
- Complex methods but very powerful tool when detailed models are not available, especially for detection
- Conclusion: requires expert knowledge to actually do the fault isolation and diagnostic part

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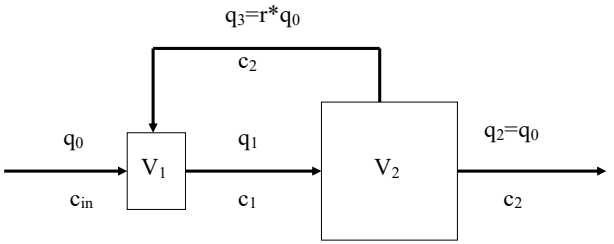
System with recycle



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Model of recycle

$$q_1 = (1+r)\cdot q_0$$
$$q_2 = q_0$$
$$q_3 = r\cdot q_0$$

$$V_1\frac{dc_1}{dt} = q_0\left[c_{in} - (1+r)c_1 + rc_2\right]$$
$$V_2\frac{dc_2}{dt} = q_0\left[(1+r)c_1 - rc_2 - c_2\right] = q_0\cdot(1+r)(c_1 - c_2)$$

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Model of recycle (2)

What happens when V_1 becomes small?

$$\frac{dc_1}{dt} = \frac{q_0}{V_1}\left[c_{in} - (1+r)c_1 + rc_2\right]$$

Large derivative – fast state

$$\frac{dc_2}{dt} = \frac{q_0}{V_2}\cdot(1+r)(c_1 - c_2)$$

The range of time constants becomes wide and the system becomes stiff!

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Model of recycle (3)

$$\varepsilon \to 0$$
$$0 = q_0\left[c_{in} - (1+r)c_1 + rc_2\right] \Rightarrow$$
$$c_1 = \frac{1}{1+r}\left(rc_2 + c_{in}\right)$$
$$\frac{dc_2}{dt} = \frac{q_0}{V_2}\cdot(1+r)(c_1 - c_2) \Rightarrow$$
$$\frac{dc_2}{dt} = \frac{q_0}{V_2}\cdot(c_{in} - c_2)$$

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Dimension reduction

- Neglecting small singular values
  - Reduction of the dimension
- Aim of multivariate statistics
  - e.g. principal component analysis (PCA)
- Idea:
  - extract underlying mechanism and represent them in a low dimensional space

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PCA

Measurement matrix — Principal components — Orthogonal coordinate system — Model error

$$\mathbf{X}=\mathbf{T}\mathbf{P}^{T}+\mathbf{E}$$

$\mathbf{E}=0$ if number of PCs = number of variables

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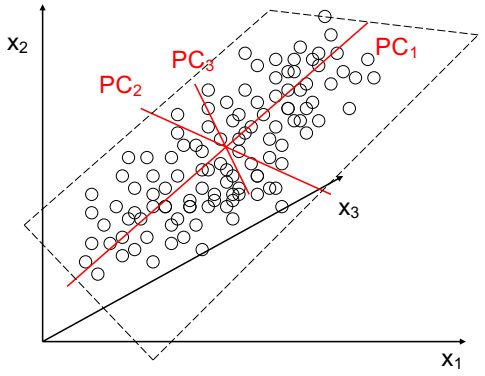
PCA



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PCA

Typically for industrial data:

- 1st PC normally describes 40-60% of the variability in a process
- A few (2-4) PCs describe >80%
- $\mathbf{E}$ ideally describes noise
- Choice of number of components crucial

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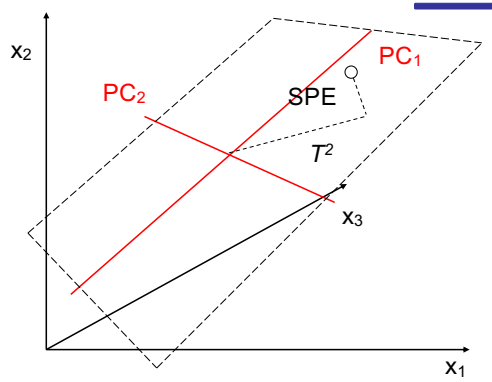
SPE and T^2 – geometrical interpretation



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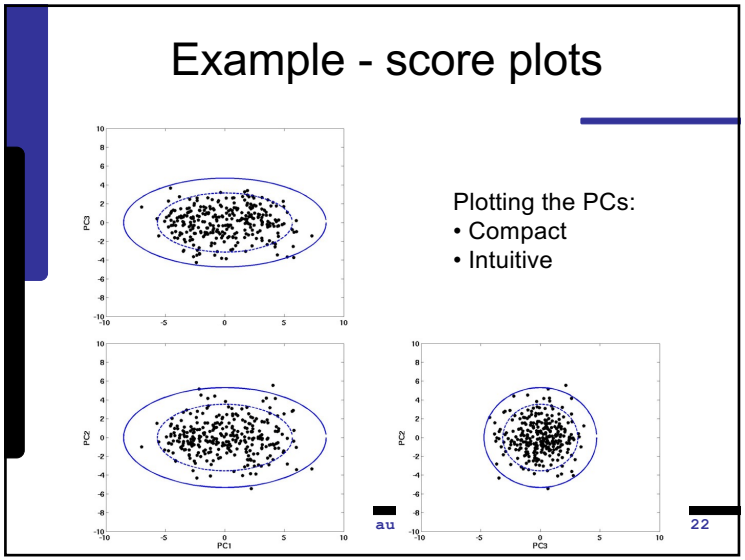
Example - score plots
Plotting the PCs:
• Compact
• Intuitive
PC3
PC2
PC1
PC2
PC3
au
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